SHORT-CIRCUIT PROTECTION IN A 25-WATT AUDIO AMPLIFIER

By Larry Blaser

I. INTRODUCTION

This note describes a positive, fast acting and reliable overload protection circuit which allows a power amplifier to be immediately restored to normal operation after a temporary short circuit at the output and protects against accidental destruction of the power transistors. Protection of this sort can be invaluable in equipment which must operate with minimum down time, as in cases where temporary overload may exist, or in equipment which must be ready for instant operation, as in military installations.

Previous amplifier designs which offer short-circuit protection commonly achieve it (1) by current limitation in the power supply or (2) by using power transistors well below their full capability and with a current-limiting device, such as a fuse or a resistance with a positive temperature coefficient (e.g., a filament lamp) in series with the load. These methods have drawbacks: Current limitation in the power supply is expensive and not always reliable under transient overload conditions; and current limitation in the load does not always afford protection against overload conditions of long duration.

The method described has neither of these disadvantages, thus allowing efficient power output stage and power supply design. A simple circuit is incorporated into the design of a conventional quasi-complementary amplifier[1, 2] which turns off the drive to the output stage when an overload condition exists at the amplifier output. Performance data is given on a 25-watt audio amplifier.

II. SHORT-CIRCUIT PROTECTION

A simplified schematic of a Class-AB push-pull amplifier is shown in Fig. 1. When a short circuit is placed across R_L, collector currents in the output transistors Q_2 and Q_3 are limited only by their forward current gain and the applied base drive. Excessive current or power dissipation in the output transistor could result in transistor failure.

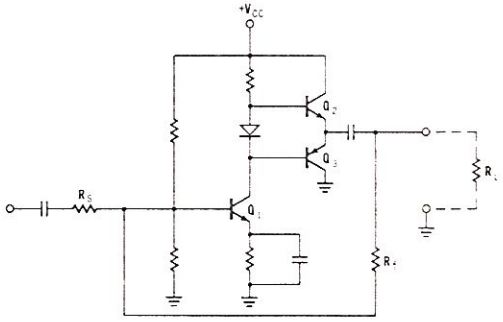

FIG. 1. Simplified schematic of Class-AB push-pull audio amplifier.

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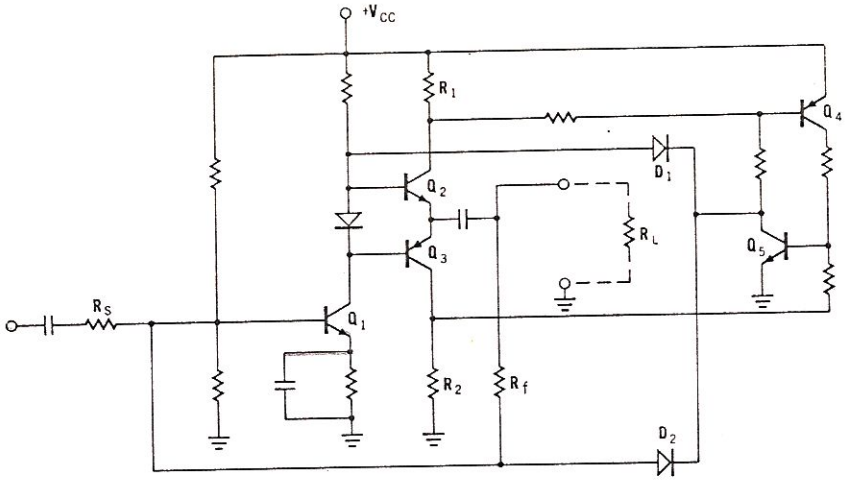

FIG. 2. Simplified schematic of audio amplifier with short-circuit protection added.

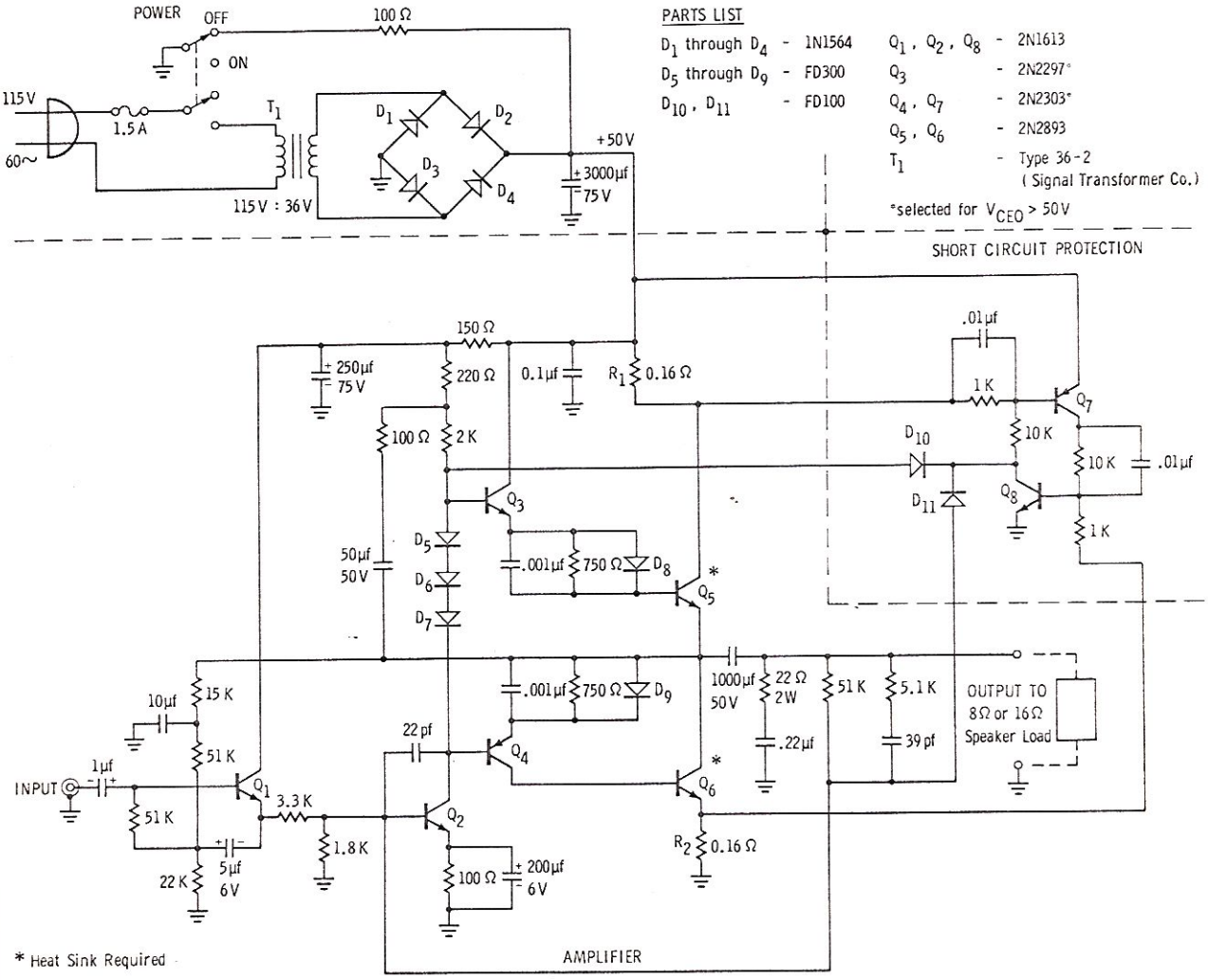

FIG. 3. 25-watt quasi-complementary audio amplifier.

Figure 2 shows the same amplifier with a circuit added to remove the drive to the output stage in the case of an overload at the output. With the amplifier in normal operation, transistors Q_4 and Q_5 do not conduct and D_1 and D_2 are reverse-biased. R_1 and R_2 are current-sampling resistors which, being small compared with R_L, do not significantly reduce the power output capability of the amplifier. An overload at the output will cause the voltage drop across either R_1 or R_2 (or both) to exceed approximately 0.6 V -- the base-emitter threshold voltage of a silicon transistor. If the voltage drop across R_1 exceeds the base-emitter threshold voltage of Q_4, then Q_4 will conduct; if the voltage drop across R_2 exceeds the base-emitter threshold voltage of Q_5, then Q_5 will conduct. If either Q_4 or Q_5 conducts, the other turns on because of cross coupling of bases to collectors and both remain on until the supply voltage is removed. With Q_5 on, diodes D_1 and D_2 conduct removing the drive current to the output transistors, Q_2 and Q_3.

The amplifier is restored to normal operation by removing the overload condition and switching off the power supply long enough for the supply voltage V_{CC} to fall to a level which will not sustain conduction of Q_4 and Q_5.

25-WATT AMPLIFIER

The silicon-transistor, quasi-complementary[1] amplifier with the short-circuit protection shown in Fig. 3 was designed to deliver 25 watts into an 8-ohm load or 13 watts into a 16-ohm load. This amplifier design is similar to a 10-watt amplifier previously described by Blaser and Franco.[2]

Damage to the output stage from a short circuit is prevented by the use of current-sensing resistors which limit the peak current* in either output transistor to about 3.5 amperes. With a V_{BE} threshold voltage of 0.55 volt on Q_5 and Q_6, 0.16-ohm resistors (R_1, R_2) are used for current sensing, allowing the amplifier to deliver its full output into an 8-ohm load. Speed-up capacitors in the base and collector of Q_7 assure rapid short-circuit protection under transient overload conditions.

The performance of the amplifier is given in Table I.

TABLE I

Music Power Rating#	25 W into an 8 Ω resistive load at 1 kc with 1% total harmonic distortion.
Continuous Power Rating	22 W into an 8 Ω resistive load at 1 kc with 1% total harmonic distortion.
Total Harmonic Distortion	0.3% : 1 kc at 220 mW and 11 W $<$1% : 20 cps to 20 kc at 220 mW and 11W
Frequency Response	20 cps to 20 kc at 1 watt within ± 1 db.
Hum and Noise	More than 90 db below 25 W.
Input Impedance	Approximately 150 KΩ.
Output Impedance	Less than 0.5 Ω at 1 kc.
Sensitivity	1 V RMS at input for 25 W output.
Power Supply Voltage	52 V at 0 watt output. 47 V at 22 W output.
Power Supply Current	80 mA at 0 watt output. 790 mA at 22 W output.
Short-Circuit Protection	No damage to amplifier with a short or low resistance connected to the amplifier output either prior to or after turn-on with an applied sine wave signal of any amplitude or frequency.

#Music Power Rating - Power output with internal power supply disconnected and replaced with fixed supply of +50 V.

*With a continuous square-wave current of 3.5 amperes peak applied to a short circuit, the power dissipated by each transistor would be 43 watts. This is excessive since the transistor power rating is 30 watts dissipation with an infinite heat sink. However, the possibility that a speech or music signal would ever approach a continuous square wave of an amplitude great enough to dissipate more than 30 watts is remote; in practice there is no problem of excessive power dissipation in the output transistors using the short-circuit protection described.

REFERENCES

1. H. C. Lin, "Quasi-Complementary Transistor Amplifier," Electronics, September, 1956.

2. L. Blaser and H. Franco, "Push-Pull Class-AB Transformerless Power Amplifiers," IEEE Transactions on Audio, January-February, 1963; also available as Fairchild Semiconductor application note APP-51.